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ABSTRACT

This paper focuses on the process of knowledge formation and scientific inquiry. Science laboratory settings may provide opportunities for students to participate in scientific inquiry. With scientific inquiry, students develop their beliefs according to experiences in which they use their prior knowledge, experimentation, and problem solving skills. This study examines the correlation between students' beliefs, instructional experiences, and approaches to the learning process. (Contains 20 references.) (YDS)

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# Relationships among epistemological beliefs, gender, approaches to learning, and implementation of instruction in chemistry laboratory.

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The overall problem of this study centers on the ways in which experiences in laboratory classes may be related to studentsí understandings of the nature of knowledge in science and their approaches to learning science. Beliefs about the origin of knowledge, the formation of knowledge and the characteristics of knowledge are called *epistemological beliefs.* It was hypothesized that the epistemological assumptions of the laboratory instruction and the studentís personal epistemological beliefs about science are related to the studentís meaningful or rote learning orientation.

A person's beliefs about the processes of knowing and the nature of knowledge in science may influence the way in which the person approaches the task of learning in science. For example, if a student believes that science knowledge consists of factual information, the student may believe that recalling the information constitutes knowing. Thus, the student may believe that learning science knowledge consists of memorizing information. In contrast, if a student believes that science knowledge is complex, resulting from interpretation of evidence in light of theories, then the student may believe that learning requires mental effort to understand the interrelationships and complexities of the knowledge (Roth & Roychoudhury, 1994; Schommer & Walker, 1995).

The ways in which students approach learning tasks have been the subject of several studies (Bretz, 1995; Cavallo, 1991; Entwistle & Ramsden, 1983). A student's

choice of using memorization as a mode of learning has been described as reflective of a surface or rote learning orientation (Cavallo, 1991; Entwistle & Ramsden, 1983).

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choice of using memorization as a mode of learning has been described as reflective of a surface or rote learning orientation (Cavallo, 1991; Entwistle & Ramsden, 1983). When a student chooses to deal with a learning task by trying to understand the relationships among new information and other information, the student's learning orientation has been described as deep or meaningful (Cavallo, 1991; Entwistle & Ramsden, 1983).

The setting of a laboratory science class may provide opportunities for students to participate in the process of scientific inquiry and the formation of knowledge. Laboratory experiences can be structured in very different ways. The laboratory experience may require students to verify the knowledge that has already been presented to them by an authority source (verification or non-inquiry laboratory). Students who experience this type of science class may come to view science as a collection of factual information that can only be "discovered" by scientists. In this situation the students will not be likely to view themselves as capable of "doing science". In contrast, during inquiry experiences, the students become actively physically and cognitively engaged in a search for explanations. The search requires the students to use prior knowledge, reasoning skills, experimentation skills, and social interactions to construct personal understanding, thus, the students "do science". Students who learn science through inquiry experiences may develop the beliefs that the justification for knowing is examination of evidence and logical reasoning. These students may come to view themselves as a source of knowledge. It is proposed that science laboratory instruction practiced as inquiry may better prepare students to understand the nature of knowing in science than laboratory instruction based upon transmission of information from an authority. The authors of laboratory science curricula may intend for lessons to be implemented in a particular way; however, the behaviors of the classroom teacher may result in the implementation of curricula in a manner that differs from what the authors intended.

## Research Purposes

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1) To characterize the instructional experiences that students have in a college chemistry laboratory setting.

2) To explore possible relationships among studentsí approaches to learning, their epistemological beliefs about science, gender and the type of instruction experienced.

## Methodology

The relationships that may exist among studentsí instructional experiences, studentsí beliefs and their approaches to learning were investigated through observations of studentsí laboratory experiences and data collection using two Likert scale student questionnaires and one open-ended response questionnaire. The studentsí laboratory experiences were characterized as either "more inquiry" or "less inquiry" based upon observational data. Scores were compiled from questionnaire instruments to represent each studentís epistemological beliefs and learning orientation.

### Sample and setting

The sample consists of college students enrolled in an introductory chemistry laboratory course at a large Midwestern university. The investigation took place in the laboratory sections of this general chemistry course. Approximately thirty students were enrolled in each laboratory section and a laboratory instructor taught either one or two lab sections. The sample consists of nine laboratory sections (one third of the laboratory sections taught that semester). The N of the sample was 232 students. Graduate teaching assistants who are chemistry majors were the instructors of the chemistry laboratory sections. The criteria for choosing the teachers was based upon observations of their classroom and laboratory instruction. Observations of the teachers' instruction were made during the first few weeks of the semester. Five teachers were chosen to participate in the study, three teachers who had taught the laboratory course previously and two novice laboratory instructors.

### Curricula

The written curricula used for the chemistry laboratory is Inquiries into Chemistry, Second Edition, (Abraham & Pavelich, 1991). The manual was designed to permit students to conduct experiments, collect data, analyze the data, interpret evidence, and draw conclusions with minimal guidance by the instructor. The laboratory manual contains two types of experiments, guided inquiry and open inquiry. Guided inquiry experiments include specific instructions concerning how to conduct the experiments and questions to answer about the collected data. Students are encouraged to discuss data and answers with classmates. The manual states, "The ëright answerí is any one that follows logically from the data and that you are comfortable with" (Abraham & Pavelich, 1991, p. 3). Students are not expected to have any knowledge of the concepts prior to experiencing the guided inquiry experiments. The open inquiry experiments allow students to extend their understanding of concepts learned through guided inquiry experiments. Students may investigate any aspect of the previously learned concept. Each open inquiry laboratory contains a number of ideas for investigation, for example, "Investigate the relationship between the volume and temperature of a gas at constant pressure" (Abraham & Pavelich, 1991, p. 231). Students are responsible for the design and implementation of the experiments. If the lessons are implemented as designed, the students should be able construct understandings of chemical concepts from experimentation, reasoning and judgement.

Laboratory meetings of each section of the chemistry classes were observed by the researcher several times throughout the semester. Field notes were taken in order to describe the actions of the teacher, the actions of the students, the interactions among the teacher and with the students, and the instructional activities. Written materials (such as laboratory guides, teacher notes and graded student lab reports) were collected in order to more completely describe the instruction.

### Instrumentation

Studentsí meaningful or rote approaches to learning were assessed using a modified Learning Approach Questionnaire (Cavallo, A. M. L., Miller, R. B., & Blackburn, M. A., 1996). The learning approach scale consists of two subscales: the Learning Approach Questionnaire--Rote (LAQR) measuring the degree of rote learning orientation, and the Learning Approach Questionnaire--Meaningful (LAQM) measuring the degree of meaningful learning orientation. The LAQR consists of 11 items and the LAQM consists of 13 items. A high score on the LAQR indicates a higher degree of rote learning and a high score on the LAQM indicates a higher degree of meaningful

learning. Cronbach alpha internal consistency reliability coefficients for subscales of the Learning Approach Questionnaire were $\underline{r}$ = .65 for LAQR and $\underline{r}$ = .80 for LAQM.

A questionnaire was adapted from existing instruments to measure students' epistemological beliefs about science. The items on the questionnaire were compiled from several instruments used in science education research that contain items related to epistemology of science (Edmondson, 1989; Rubba, 1977; Ryan & Aikenhead, 1992). The Science Knowledge Questionnaire consists of 32 Likert scale items. A high score on the SKQ would represent a view of the epistemology of science that is *constructed* or *reasoned* [more "mature" according to Schommer (1990), or "worldly" according to Ryan & Aikenhead (1992)]. A low score on the SKQ would represent a view of epistemology of science that is *received* [more "naive" according to Schommer (1990), and Ryan & Aikenhead (1992)]. The Science Knowledge Questionnaire had a Cronbach alpha coefficient of $\underline{r}$ = .78.

Students were also asked to complete three open-ended questions concerning their perceptions of their teachers and their laboratory experiences at the end of the semester. The questions were adapted from Edmondson (1989): 1) What types of things are you supposed to learn from the laboratory portion of Chemistry 1315? 2) Do you think that what you do in this laboratory could be described as generating scientific knowledge? Why or why not? 3) If you just went into the lab and conducted experiments without a teacher present, would that count as generating scientific knowledge? Why or why not?.

## Results and Discussion

### Characterization of studentsí experiences

Observations of five teachersí laboratory instruction revealed differences in how the inquiry-based curricula was implemented. The differences in the teachersí actions included varying introductions to the activities, the nature of the directions given to the students, presence or absence of explicit discussion concerning issues of experimentation, and the ways in which the teachers interacted with their students during the laboratory. Two patterns of curriculum implementation emerged from the data, less inquiry and more inquiry.

The differences in teacher behaviors noted in the field notes of the observations led to the categorization of each teachersí instruction as more inquiry or less inquiry. Two experienced teachers and one novice teacher implemented instruction in such a way that student inquiry was encouraged and supported ("more inquiry"). The directions given by these teachers included the use of equipment and safety, general directions to focus studentsí attention on the concepts being investigated (during guided inquiry laboratories), instructions to design and implement experiments (during open inquiry laboratories). During the laboratories, these teachers asked the students to describe the question they were trying to answer, frequently discussed issues of experimentation (variables, control, replicability, error analysis), responded to studentsí questions with encouragement for the students to try to find answers on their own, and probed studentsí understandings during discussions. In the more inquiry classes, students constructed understanding of the concept through their experimentation.

One experienced teacher and one novice teacher implemented instruction in such a way that the goal of the laboratory experience was to complete the exercise ("less inquiry"). The directions given by these teachers was detailed and often included telling the students what the results of the experimentation should be. During open inquiry laboratories, the teachersí directions limited studentsí choices of systems to investigate. During the laboratories, these teachers tended to give students answers rather than encouraging students to find answers on their own. The teachers would often tell the students how to design and perform the experiment, what the results of the experiment would (or should) be, and what the interpretation of the results should be. Accordingly, there was little discussion about issues related to experimenting. The students in the less inquiry classes had fewer experiences engaging in the processes of scientific inquiry than students in the more inquiry classes.

The epistemological messages inherent in more inquiry instruction included: (a) the student was capable of forming a question and designing an experiment; (b) the student could interpret the experimental evidence to answer the question; and (c) if the studentís results did not correspond to the results of others, the student was capable of examining the experiment for sources of variability. The epistemological assumptions of more inquiry instruction represented a view of knowledge as constructed by the student through experimentatícn and reasoning. Therefore, the student could serve as the source of scientific knowledge and the justificatíon for knowing stemmed from logical interpretation of evidence in the more inquiry classes.

The epistemological messages inherent in less inquiry instruction included: (a) information gathered by experimentation was only valid if it agreed with the text or the teacher, (b) the student was not capable of designing experiments or generating scientific knowledge, and (c) the experimental evidence that the student gathered was most often incorrect for reasons that the student did not know. The epistemological assumptions of less inquiry instruction represented a view of knowledge as received from authoritative others. Since experimental data could be incorrect for inexplicable reasons, the justification for knowing stemmed not from interpretation of evidence, but only from the opinions of authority figures.

Studentsí perceptions of their experiences

Student responses to open ended question #1 indicate varied notions of the purpose of the laboratory: to some students the lab is just a place to repeat what was learned in lecture, to others the lab is where the connection to real life is, to many students learning laboratory techniques is important, and to some students the laboratory represents an opportunity to engage in independent thinking.

In response to question #2, some students say knowledge is generated in the laboratory, others say it is not. The studentsí responses seem to depend upon their definition of *scientific knowledge* . Some students say yes if "generating scientific knowledge" means personal construction of understanding. In contrast, other students say no if "generating scientific knowledge" means that something is discovered/figured out that is new to the entire scientific community. A few students identify both positions as valid. Many students agreed that they were generating scientific knowledge in the laboratory because they were performing experiments and thinking scientifically. Other students responded that they did not generate scientific knowledge because they did not think about the experiments.

In response to question #3, most students stated that they did or did not generate scientific knowledge in laboratories for the same reasons as they gave for question #2. Many students were concerned that they would get the answer "wrong" if the teacher was not present to confirm the findings and make sure the experiment was performed correctly. Some students responded that if the teacher did not tell them what to learn, they wouldnít gain knowledge from the experiments

Evidence from the observations and the open-ended response questionnaire indicated that some students perceived epistemological messages in their instruction. Many students identified the teacher as the authoritative source of knowledge in the laboratory, perhaps due to their prior experiences in science classes. Students may come to class with preconceptions about science laboratory classes formed from their previous experiences. Studentsí perceptions of the laboratory class may be filtered through their expectations of learning and teaching in science classes. When students described the laboratory as a place to confirm or reinforce what was learned in the lecture, they were expressing their preconceptions of science laboratory classes. In fact, the lecture and laboratory portions of the course were coordinated so that concepts were explored in the laboratory before they were mentioned in the lecture. Thus, the studentsí responses to the question about the purpose of the laboratory course reflect not only their experiences in this laboratory class, but also their preconceptions of science laboratory classes.

Students tended to equate personal learning of science with "generating scientific knowledge". This connection may exist because the students related their experiences with science with their classroom experiences. Larochelle and Desautels (1991) reported difficulty distinguishing studentsí ideas about science from their representations of school-based science learning during interviews with 25 high school students. Other researchers have also linked ideas about knowledge with ideas about learning (Baxter Magolda, 1992; Roth & Roychoudhury, 1994; Schommer, 1990, 1993). In the current study, students expressed concerns about finding the correct answers from their experiments. Perhaps the identification of "generating science knowledge" with personal learning of science in a class explains the studentsí concerns.

Many students who identified "generating scientific knowledge" as discovering something new to the entire scientific community did not see themselves as sources of scientific knowledge. They perceived that their experiments only replicated or verified the findings of others. For these students, the source of scientific knowledge may have been professional scientists.

Other students equated experimentation and critical thinking with the generation of scientific knowledge. These students identified themselves as sources of scientific knowledge when they used critical thinking and performed experiments. For these students, the justification for knowing may have been the act of experimentation and

thinking.

Some students responded that they could generate scientific knowledge without the teacher because they would have had to think more actively about the experiment. Some students equated their laboratory experiments with "following a recipe"; saying that the experiments required little thought. These statements may indicate that these students engaged in the laboratory experiments only to the extent necessary to complete the course requirements. Perhaps studentsí perceptions of the laboratory assignment influenced the studentsí meaningful learning sets. If students perceived that the experiment required only following directions, then they might not have found it necessary to attempt to make sense of the experiment. In contrast, if students perceived that successful completion of the laboratory required that they make sense of the experiment, then they may have attempted to cognitively engage in the activity. Therefore, studentsí perceptions of the potential meaningfulness of the task may influence whether they chose to utilize a rote or meaningful learning approach.

Relationships among studentsí approaches to learning, their epistemological beliefs about science, gender and the type of instruction experienced

Table 1: Point-biserial correlation

| | LAQR | SKQ | INSTR | GENDER |
|---|---|---|---|---|
| LAQM | -.023 | .055 | .078 | -.002 |
| LAQR | --- | -.143* | -.031 | -.086 |
| SKQ | --- | .002 | -.231** | |
| INSTR. | --- | -.076 | | |

* $p < 0.05$

** $p < 0.001$

Gender and Epistemological Beliefs

Epistemological beliefs were significantly correlated with gender of students

($r$ = -.231, $p$ = .000). Male students were more likely to believe in the reasoned nature of knowledge in science, while female students are more likely to believe in the received nature of knowledge in science. An analysis of variance was performed to investigate the possible interaction of gender and type of instruction on studentsí epistemological beliefs. Although the interaction was not significant ($F$= 3.64, $p$=.058), the possibility that the epistemological beliefs of males and females interact differently with more inquiry or less inquiry instruction is a topic for further investigation.

Type of Instruction and Epistemological Beliefs

Type of instruction was not correlated with epistemological beliefs as measured by the SKQ. Previous research concerning epistemological beliefs demonstrated that change in epistemological beliefs is gradual (Perry, 1968; King & Kitchener, 1990). In the present study, if studentsí epistemological positions developed throughout their life experiences with science (particularly with school science), brief, recent experiences may not have been sufficient to influence studentsí responses to questions on the SKQ. Edmondsonís (1989) finding that students simultaneously held conflicting epistemological positions suggests that students do not necessarily integrate the epistemological assumptions of their recent experiences into their previously held positions. Edmondson concluded that students had developed distinct, parallel ways of knowing. Perhaps students answered the SKQ items without referencing their recent experiences in chemistry laboratory because their epistemological views of *science in a classroom* differed from their views of *science as an enterprise and as the work of professionals* . The existence of separate conceptions of science knowledge could explain why some students reported that they generated scientific knowledge during the chemistry laboratories, but also scored very low on the Science Knowledge Questionnaire.

The instruction of the less inquiry teachers may have encouraged the students to conceptually separate the knowledge they gained through direct experiences from knowledge transmitted to them. These teachers directed students to ignore their own experiences (the results they saw in the laboratory) in favor of the "correct" results that they should have observed. The students were left with the choice of disbelieving their own experiences or creating two versions of the phenomenon - *what they saw* and *what they were told* . In contrast, the more inquiry teachers may have helped students reconcile the two sources of knowledge by encouraging and assisting students to find the reasons why their results differed from the results in the text. The more inquiry teachers were supporting studentsí integration of different ways of knowing.

Type of Instruction and Learning Approach

Type of instruction was not correlated with meaningful or rote learning orientation. Cavallo and Schafer (1994) also found little effect of type of instruction (reception versus generative) on studentsí meaningful learning.

The laboratory section is only a part of the chemistry course, the students also attend three hours of chemistry lecture presentations each week. The laboratory experience may not have been a strong enough treatment to influence studentsí learning orientations in comparison to the lecture portion of the course. Despite written and verbal directions for the students to consider only the laboratory portion of the course when completing the Learning Approach Questionnaire, some of the items refer to lectures, textbook readings and examinations. The students may have been unable to answer these items based solely on their laboratory experiences, thus they may have considered their experiences in chemistry lecture when responding to these items.

Although the two groups of teachers implemented the curriculum differently, the studentsí lab manual may have been a greater influence on studentsí perceptions of the instruction than the teacherís behaviors. Pavelich and Abraham (1979) used the LPVI to describe laboratory instruction based upon studentsí ranking of descriptive statements. The students in Pavelich and Abrahamís (1979) study focused most on the laboratory reports they had to write, next on the requirements of the laboratory guide, and then on their own activities during the laboratory. Statements that described the instructor were not as highly ranked as statements which described the laboratory manual and the studentsí own activities. The studentsí focus on the laboratory manual and their own activities (Pavelich & Abraham, 1979) may explain why type of instruction was not a predictor of meaningful or rote learning approach in the present study. Contact with the teacher during a laboratory was limited due to the number of students in each laboratory section, therefore students relied heavily on the laboratory manualís instructions for assistance during the guided inquiry laboratories. Students also used the laboratory manual when preparing the laboratory reports which were the basis of their grades in the laboratory portion of the course. All students used the same laboratory manual and no differences were detected in the grading of the laboratory reports. If the students in the present study focused more on the laboratory manual and their laboratory reports than on the actions of their teacher, implementation of instruction by the teacher may not have influenced the studentsí approaches to learning or their perceptions of the instruction.

Meaningful Learning Approach and Epistemological Beliefs

The hypothesized relationship between the epistemological belief in reasoned knowledge and meaningful learning orientation could not be supported in this study. Meaningful learning approach was not related to studentsí epistemological beliefs as measured by the Science Knowledge Questionnaire. Students reported using meaningful approaches to learning regardless of beliefs in knowledge as reasoned or received. Since few students reported highly meaningful learning orientations and no students reported strongly held beliefs in reasoned knowledge, the correlation could only assess the relationship between low-midrange meaningful orientation and received-midrange epistemological beliefs. The relationship between highly meaningful learners and their epistemological beliefs remains unknown. Students reported using low and midrange meaningful approaches to learning regardless of their epistemological beliefs.

However, the measure of association (eta squared) of LAQ-M and SKQ scores for the sample of this study indicated shared variability of 18.5%. Although low-midrange meaningful learning approach and received-midrange epistemological beliefs were not related in a linear fashion, they may be jointly influenced by unmeasured variables. Future research should strive to identify variables that influence both meaningful learning orientation and epistemological beliefs.

Rote Learning Approach and Epistemological Beliefs

Rote learning approach and epistemological beliefs were correlated

$r$ = -.143, $p$ = .03). Students who believe in the reasoned nature of science knowledge use fewer rote approaches to learning than students who believe in the received nature of knowledge. This result agrees with Edmondsonís (1989) findings that male students held more received views of science knowledge and tended to use rote learning strategies. The finding agrees with the theoretical framework of this study. If students believe that knowledge is certain, and the source of knowledge and justification for knowing is an authority, it follows that learning requires only rote strategies such as memorization. If knowledge is simple, there is no reason to try to make connections between new information and prior knowledge.

Eta squared, the measure of association of LAQ-R and SKQ scores for the sample of this study, indicated shared variability of 18.6%. It is possible that rote learning orientation and received epistemological beliefs are jointly influenced by unmeasured variables. Further research is needed to identify the factors that influence rote learning orientation and belief in received knowledge.

## Conclusions

Students became a source of scientific knowledge for themselves when they were allowed to be and when they were encouraged to do so. When the teacher presented himself as an authoritative source of knowledge, the students accepted him as such. The justification for knowing in the chemistry laboratory appeared to depend upon the perceived source of knowledge. The agreement of a source of authority was the justification for knowing in the less inquiry classrooms. The results of experimentation and logical reasoning were the justification for knowing in the more inquiry classrooms. Therefore, the epistemological assumptions of more inquiry and less inquiry instruction differed due to the ways the teacher implemented the curriculum. It is notable that studentsí perceptions of instruction may have been influenced to a greater extent by the laboratory manual or their prior experiences than by their instructor.

The epistemological messages inherent in the two types of instruction did not appear in studentsí responses to the Science Knowledge Questionnaire. Epistemological beliefs form as a result of an accumulation of experiences; the laboratory experience was of limited duration and may have been confounded by the lecture portion of the course. Considering the results of the SKQ, it is interesting that many students reported that they generated personal scientific knowledge during the chemistry laboratories. Perhaps these students had developed parallel ways of knowing about science.

Although type of instruction was not correlated with learning approach as measured in this study, the open-ended responses point to studentsí perceptions of classroom tasks as influential in their choice of meaningful or rote learning strategies. Students appeared to assess the demands of a task as presented to them by the laboratory manual and their teacher, and to respond with the learning approach that would accomplish the task. Thus, a studentís use of meaningful or rote learning strategies may vary from task to task. This interpretation is supported by the finding that meaningful learning approach and rote learning approach are separate constructs for this sample.

Rote learning approach was predicted by belief in reception of knowledge from authorities for this sample of students. In this study, students who tended to believe that knowledge comes from an external authority were more likely to attempt to memorize the information than to try to "make sense" of the information for themselves. This relationship was hypothesized by Hofer & Pintrich (1997) and Perry (1981) and confirmed through this study.

When an authority presents information to a student, the student makes a choice about how to learn the information. The student may choose to try to reconcile the new information with prior knowledge, but to do so may result in conflict between knowledge from experiences and from the authority source. In order to accept the opinions of authorities which might be in conflict with experiential knowledge, a student may choose to utilize rote approaches to learning. In this case, the student may choose to memorize the new information without attempting to integrate it with prior knowledge. The student rotely learns what the authority presents because this information is needed for evaluation. However, the student also "knows" about the way the natural world works as the result of direct experiences. Therefore, a rote approach to learning information provided by authorities may help a student maintain of parallel ways of knowing about science.

## Implications of the Study

Proper implementation of inquiry instruction may require that teachers understand the purposes behind the curriculum design. One purpose of science education is to introduce students to the ways scientists investigate the world. When science teachers present themselves as the authoritative source of knowledge, they are not representing the epistemology of scientific knowledge accurately. Scientific epistemology is more accurately portrayed when science teachers engage students in the processes of experimental design and critical analysis of results. Science teacher education should include analysis of the epistemological implications of curricula and instructional behaviors. Teachers need to be aware of the implicit messages their teaching behaviors send to their students.

Fortunately in this study, many students in the less inquiry classrooms appeared to be influenced by the written curriculum to a greater extent than they were by the way their teachers implemented the curriculum. However, the more inquiry teachers may have helped their students to develop a personal scientific epistemology that more closely reflects the nature of the scientific enterprise. If science teachers were educated to implement inquiry curricula in the "more inquiry" fashion, their students would benefit. If students hold parallel epistemological positions, experiencing more inquiry instruction may help bring their personal scientific epistemologies closer to their ideas about professional scientific epistemology. Then students may find it easier to integrate their parallel knowledge systems into a coherent epistemological theory. Inquiry instruction in introductory chemistry courses in not commonplace in the United States. Identification the benefits of inquiry instruction for students may encourage more colleges to adopt an inquiry curriculum.

The findings of this study contribute to greater understanding of the relationship between studentsí ideas about learning and knowledge. The shared variability of meaningful learning approach and epistemological beliefs. and rote learning approach and epistemological beliefs indicates that these constructs may be jointly influenced by other factors. This finding provides a direction for future research.

One important result of this study indicates that meaningful and rote approaches to learning are not in opposition. Theoretically, a student would use either meaningful or rote approaches to learning. The findings of this study are not consistent with this theoretical relationship. One interpretation of this finding is that students may use a combination of learning approaches based upon their perceptions of the demands of a task. If so, then teachers who provide meaningful learning tasks and who have the expectation that students learn in a meaningful way may encourage the students to do so.

## Further Research

Further research should investigate the relationships between learning approach and epistemological beliefs in other contexts (traditional chemistry laboratory instruction, inquiry biology laboratory instruction, etc.). These relationships may also be investigated in younger and older students to investigate the possible influences of maturity, intellectual development, level of education and types of education experiences on epistemological beliefs and learning approaches. Many factors are hypothesized to influence an individualís epistemological beliefs (Hofer & Pintrich, 1997). Further research should strive to reflect the complexity of influences on epistemological theories.

The results of this study suggested that students may utilize independent parallel ways of knowing about science. Further research should search for ways to detect and document the existence of parallel knowledge systems about personal science epistemology, school-based science epistemology or professional science epistemology. If these parallel ways of knowing exist, can using instructional methodology which encourages students to adopt meaningful learning approaches help students integrate their disparate conceptions of knowledge? This question offers a direction for future research.

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